



NASA SBIR 2021 Phase I Solicitation

Z8.10 Wireless Communication for Avionics and Sensors for Space Applications

Lead Center: ARC

Participating Center(s): GRC, JPL, LaRC, MSFC

Scope Title:

Modular and Flexible Wireless Avionics Architectures and Wireless Sensing and Integrated Avionics for Space Applications

Scope Description:

The Wireless Communication for Avionics and Sensors for Space Applications subtopic solicits proposals to develop enabling concepts, components, and subsystems based on innovative avionics architectures for small spacecraft. Of interest are wireless systems that demonstrate reliable data transfer across avionics components, subsystems, and interfaces to simplify system integration, reconfiguration, and testing. These can range from developmental and flight instrumentation systems used for qualification and diagnostics on large spacecraft to full-up wireless avionics for small spacecraft. Solutions that enable new avionic architectures and provide capabilities that expand mission performance while decreasing the size, weight, and power consumption (SWaP) and cost of the resulting spacecraft are highly desirable. The goal of this effort is to mature wireless avionics technology that facilitates the reuse of components, subsystems, and software across multiple spacecraft and missions while reducing production and operating costs.

Modularity is defined as utilizing a set of standardized parts or independent units to form a full avionics system, and flexibility allows adapting modular components across different configurations, missions, and design stages. For example, wireless subnets improve modularity by eliminating the physical data connections from each component, simplifying physical integration. The scope is intended to range from simple wireless sensors to complete avionics systems, including software incorporating functions compatible with common spacecraft components. This means being able to integrate a given component or entire subsystem into flight hardware and software using object-oriented frameworks, allowing components or functions to be added to a new or existing spacecraft design without requiring significant changes to the other nonrelated components or subsystems.

This subtopic also solicits proposals to develop techniques, components, and systems that reduce or eliminate the dependency on wires, connectors, and penetrations for sensing and for the transmission of data and power across avionics subsystems, interfaces, and structures. Of interest are techniques that enable new applications through the use of innovative methods such as the use of flexible materials and additive manufacturing. For example, the use of additive manufacturing and 3D printing to embed avionics components such as antennas, sensors, transmission lines, and interface functions into a spacecraft structure during the design and manufacturing process

can increase efficiency while maintaining structural integrity. Similarly, the use of thin and flexible materials to construct passive wireless sensors enables sensing systems for structures such as parachutes and inflatable spacecraft without breaching the pressure interface. Systems that are applicable to small spacecraft (typically 6U/12U/24U CubeSats, including ESPA-class (Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter)) but scalable to large vehicles can result in a significant reduction of risk for more complex and longer duration missions. Near-term missions include cislunar, lunar orbiting, lunar landed, and exploration precursor missions; low Earth orbit (LEO) €œswarms€ for Earth science and heliophysics; and disaggregated cooperative ensembles and sustained infrastructure for human exploration. New applications might include manned spacecraft inspection, repair, communications support, and related areas. Proposals that provide reliable performance in extreme environments and that show a path to a flight demonstration are preferable.

The subtopic solicits developments in wireless avionics and wireless sensing for small spacecraft and may include technologies that:

1. Improve the reliability and applicability of wireless avionics for small spacecraft with significant improvements in subsystem size, mass, and volume, particularly if the technology can simplify the spacecraft fabrication, test, and integration process.
2. Allow innovative architectures for wireless avionics featuring plug-and-play software supporting modular subsystems that can be easily incorporated into specific small-satellite missions.
3. Improve fault detection aboard spacecraft using wireless sensor systems to augment current wired sensors and which include the capability of adding sensors to address developmental and flight instrumentation use.
4. Use innovative techniques for embedding sensors and other avionics components into a spacecraft to reduce or eliminate large and heavy cables and connectors, or that enable data transfer inside and across rotating mechanisms and pressure interfaces or into remote locations where it is difficult or unfeasible to run cables or where cables are at risk of failure.
5. Use additive manufacturing of wireless components such as antennas, sensors, and processing elements to create new components that may be smaller and lighter than current products. These new components could possibly be embedded into materials and structures that enable in situ structural health management, contributing to the development of smart structures and materials.
6. Include sensors and actuators that can be distributed among cooperative spacecraft to enable automated inspection of space assets or resource detection at the surface of the Moon, Mars, or other celestial bodies.

Key performance parameters (KPPs) would include improvements of at least a factor of 2 over existing technology in size, mass, and power consumption for sensors and associated components for a wireless instrumentation system. Improvements of sensor network throughput greater than 5— the current 2-Mbps performance is desired, along with reduction of latency and incorporation of timing information.

Expected TRL or TRL Range at completion of the Project: 3 to 6

Primary Technology Taxonomy:

Level 1: TX 02 Flight Computing and Avionics

Level 2: TX 02.2 Avionics Systems and Subsystems

Desired Deliverables of Phase I and Phase II:

- Hardware
- Prototype
- Software
- Research
- Analysis

Desired Deliverables Description:

Possible deliverables include benchtop hardware systems that demonstrate reliable wireless interconnectivity of

two or more modules with a host flight central processing unit (CPU), or payload/developmental flight instrumentation (DFI) processor, inside a CubeSat or small-satellite form-factor bus. This system need not be flight ready, but it should be in a path to a flight demonstration that would serve as technology maturation and risk reduction activity for larger NASA missions such as Gateway and other Artemis projects.

Specific Phase I deliverables include:

- Methods of improving reliability of wireless avionics technology.
- Redundancy methods to broaden mission applicability.
- Improvements in tolerance to extreme environments including radiation.
- Novel avionics architecture definition and demonstration.
- Software support for redundant modular avionics.
- Plug-and-play methods for handling dynamic changes to avionics configuration.
- Fault detection and recovery for wireless avionics.
- Improvements in spacecraft production.
- Improvements in spacecraft integration and test.
- Technologies that use additive manufacturing technology for embedded avionics systems that reduce cables, connectors, and penetrations and show a path to a full solution.
- Sensors and sensor systems based on current technology needs to develop point solutions that are applicable to NASA missions in near- to mid-range time frames.

Phase II deliverables should build upon the work completed in Phase I to demonstrate the new technology at a higher Technology Readiness Level (TRL) with alignment to NASA mission needs:

- Demonstration showing the key innovations of the developed technology.
- Demonstration of specific new mission capabilities.
- Delivery of prototype hardware for NASA evaluation.

State of the Art and Critical Gaps:

Development of small satellites missions benefit from a growing number of users worldwide. This means there may be a large pool of COTS components available for a specific mission (depending on the type and class of mission). A variety of command and data handling (C&DH) developments for CubeSats have resulted from in-house development, from new companies that specialize in CubeSat avionics, and from established companies who provide spacecraft avionics for the space industry in general. Presently there are a number of commercial vendors who offer highly integrated systems that contain the onboard computer, memory, electrical power system (EPS), and the ability to support a variety of input and output (I/O) for the CubeSat class of small spacecraft.

Wireless networks have been incorporated as crew support aboard the International Space Station (ISS). Wireless sensor networks have been flown as demonstrations. Dynamic self-configuring wireless networks have been evaluated in the lab. AIAA has defined the Space Plug-and-Play (SPA) standard, and flight demonstrations are planned.

The maturation of additive manufacturing and 3D-printing technology are making embedded wireless sensors and avionics a possibility. Embedding transmission lines, antennas, connectors, and sensors onto a spacecraft structure turns that structure into a multifunctional system that reduces or eliminates bulky cables and connectors. Embedded passive wireless sensors can greatly increase sensing and telemetry capabilities, including providing low-cost techniques for vehicle health management in future missions. Moreover, flexible embedded passive sensors created with conductive and functional fabrics are enabling new opportunities for sensing in surfaces and systems where sensing has been traditionally absent, such as parachutes and inflatable structures.

Relevance / Science Traceability:

NASA and other space agencies are exploring the application of SmallSats for deep space missions. The availability of modular wireless data connectivity alleviates complexity in testing and integration of systems. Modular components allow easier reconfiguration and late additions to any design. This is a benefit conferred on any spacecraft of any size, with the larger systems benefiting from savings in mass due to a larger reduction in cable harnesses and connectors.

References:

State of the Art: Small Spacecraft Technology:

https://www.nasa.gov/sites/default/files/atoms/files/soa2018_final_doc.pdf

Fly-by-Wireless Conference: <https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20070013704.pdf>

Fly-by-Wireless Conference 2007: <https://ntrs.nasa.gov/search.jsp?R=20070013704>

Fly-by-Wireless Update (2012): <https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20120010669.pdf>

Wireless Aircraft Interconnect (WAIC) Systems:

<https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170000686.pdf>

Backscatter Systems for WAIC: <https://ntrs.nasa.gov/search.jsp?R=20180004760>

NASA Armstrong Patent: <https://technology.nasa.gov/patent/DRC-TOPS-42>

NASA Trade Study:

https://pdfs.semanticscholar.org/b7d6/e6d92ec78b6bee4cffd5a7f613b90b4508b8.pdf?_ga=2.244696965.1804159109.1563897519-1127952606.1563032260

Passive Wireless Sensor Technology Workshops: <https://attend.ieee.org/wisee-2019/program/workshops/>